Leptonic asymmetry in $t\bar{t}$ production at CDF

Stefano Camarda[1]

LHCP 2013
May 11-18, 2013
Barcelona

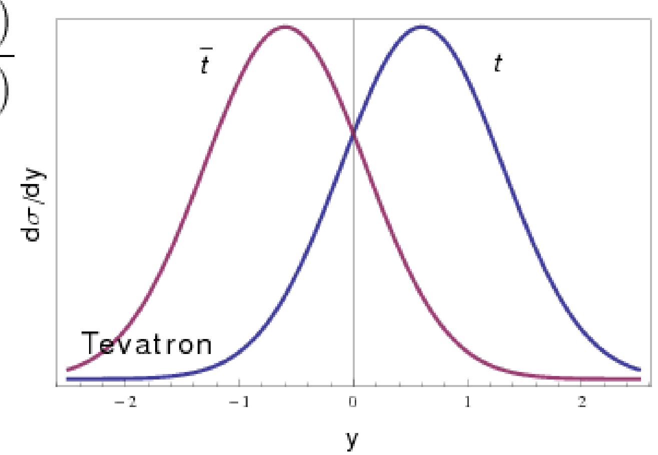
[1]Formerly IFAE - Barcelona

On behalf of the CDF Collaboration

Motivation

Tevatron experiments report ~2 σ excess on $t\bar{t}$ A_{FB}

$$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$



CDF 16.4 ± 4.5 % (6.6% POWHEG + EW)
D0 19.6 ± 6.5 % (5.0% MC@NLO)

Probe of beyond SM physics

A_{FB} induces
Leptonic asymmetry

$$A_{\mathrm{FB}}^{lep} = \frac{N\left(qy_l > 0\right) - N\left(qy_l < 0\right)}{N\left(qy_l > 0\right) + N\left(qy_l < 0\right)}$$

- Depends only on lepton's charge and direction → very precise measurement
- Provide complementary information to A_{FB}

Previous results from D0

Channel	A^{lep}_{FB}		L
Lepton +jets	15.2 ± 3.4	Arxiv:1110.2062	5.4 fb^{-1}
Dilepton	5.3 ± 7.9 ± 2.9	Arxiv:1207.0364	5.4 fb^{-1}
combined	11.8 ± 3.2	Arxiv:1207.0364	5.4 fb^{-1}

Call for precise measurements with the full Tevatron dataset

Leptonic asymmetry A^{lep}_{FB} in $t\bar{t}$ production

$$A^{lep}_{\rm FB} = \frac{N(qy_l > 0) - N(qy_l < 0)}{N(qy_l > 0) + N(qy_l < 0)}$$

Sources of leptonic asymmetry

$t\bar{t}$ asymmetry

$A_{FB} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$
0 at LO(a_s^2) QCD
~7% at NLO(a_s^3) QCD
HO corrections EW, PMC 9%-12%

SM

top polarization

$P = \frac{N(t_R\bar{t}_R) - N(t_L\bar{t}_L)}{N(t_R\bar{t}_R) + N(t_L\bar{t}_L)}$
0 in the SM
P > 0 → positive contribution to A^{lep}_{FB}
P < 0 → negative contribution to A^{lep}_{FB}

BSM

Leptonic asymmetry A^{lep}_{FB} in reference models

CDF Run II Preliminary $\int \mathcal{L} = 9.4/fb$

Model	$A^{\Delta y}_{FB}$	A^{lep}_{FB}	Polarization	
ALPGEN	$-0.000\,(1)$	$+0.003\,(1)$	$+0.009\,(2)$	LO Standard Model
POWHEG	$+0.052\,(0)$	$+0.024\,(0)$	$+0.001\,(1)$	NLO Standard Model
Octet A	$+0.156\,(1)$	$+0.070\,(2)$	$-0.005\,(3)$	LO unpolarized axigluon
Octet L	$+0.121\,(1)$	$-0.062\,(1)$	$-0.290\,(3)$	LO left-handed axigluon
Octet R	$+0.114\,(2)$	$+0.149\,(2)$	$+0.280\,(3)$	LO right-handed axigluon

ALPGEN	LO+PS	No asymmetry
POWHEG	NLO+PS	2.4% A^{lep}_{FB}
Octet A	Unpolarized axigluon (2.0 TeV/c^2, narrow)	7% A^{lep}_{FB}
Octet L	Left polarized axigluon (200 GeV/c^2, Γ=50 GeV/c^2)	reduced A^{lep}_{FB}
Octet R	Right polarized axigluon (200 GeV/c^2, Γ=50 GeV/c^2)	enhanced A^{lep}_{FB}

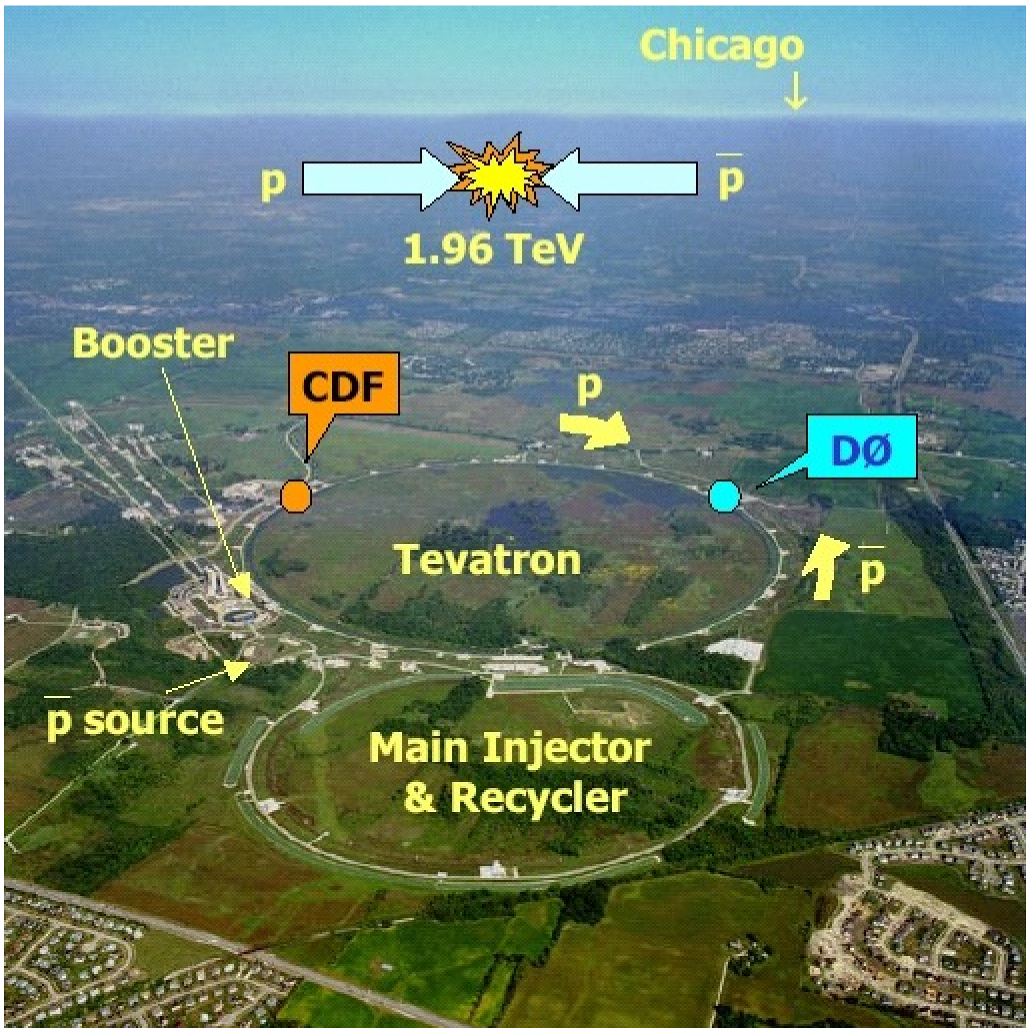
BSM reference models

SM higher order corrections

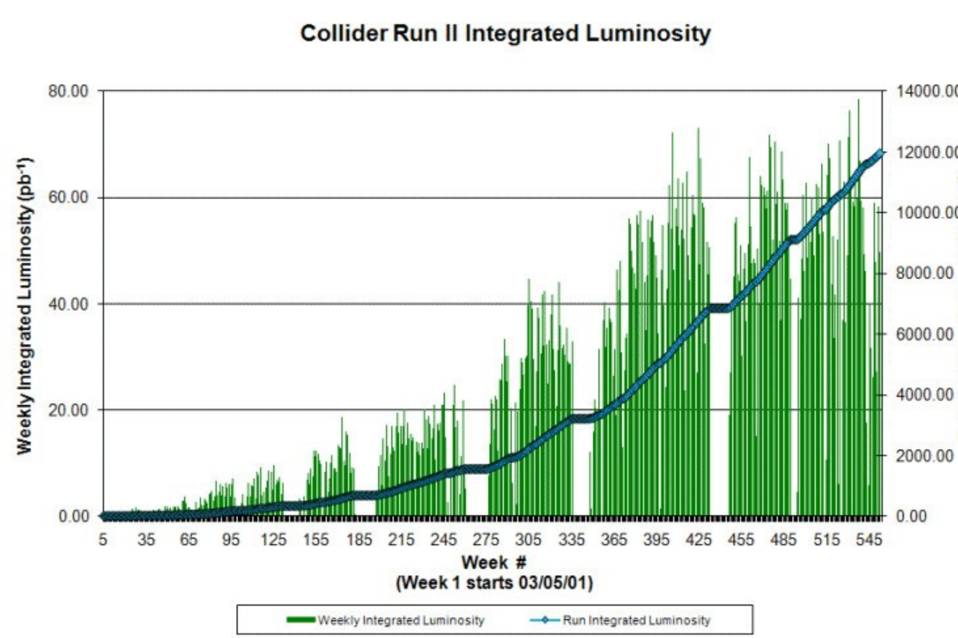
Soft gluon resummation	Small effect	arXiv:1106.6051
EW corrections	25% enhancement	arXiv:1205.6580
NLO scale variation	30% uncertainty	ArXiv:1204.1513
PMC scale setting	40% enhancement	arXiv:1205.1232
NNLO QCD	Not yet known	

Tevatron Run II

Full Tevatron Run II dataset
12 fb^{-1} delivered – 10 fb^{-1} for analysis



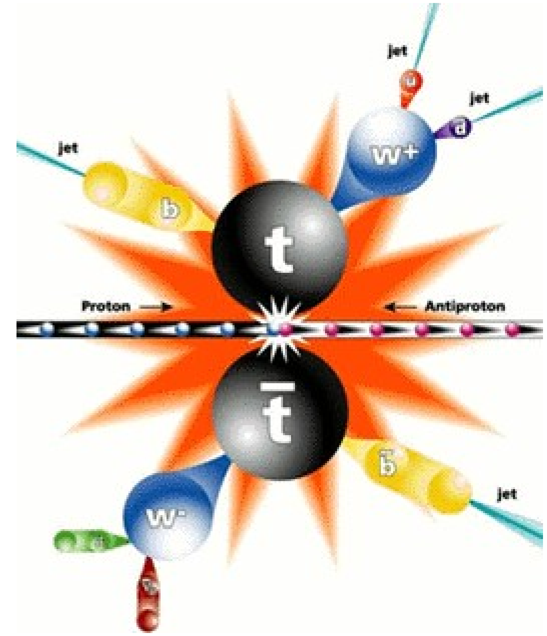
- $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
- Peak instantaneous luminosity ~ 4 x 10^{32} cm^{-2} s^{-1}
- 10 years of data acquisition, end of operation in September 2011

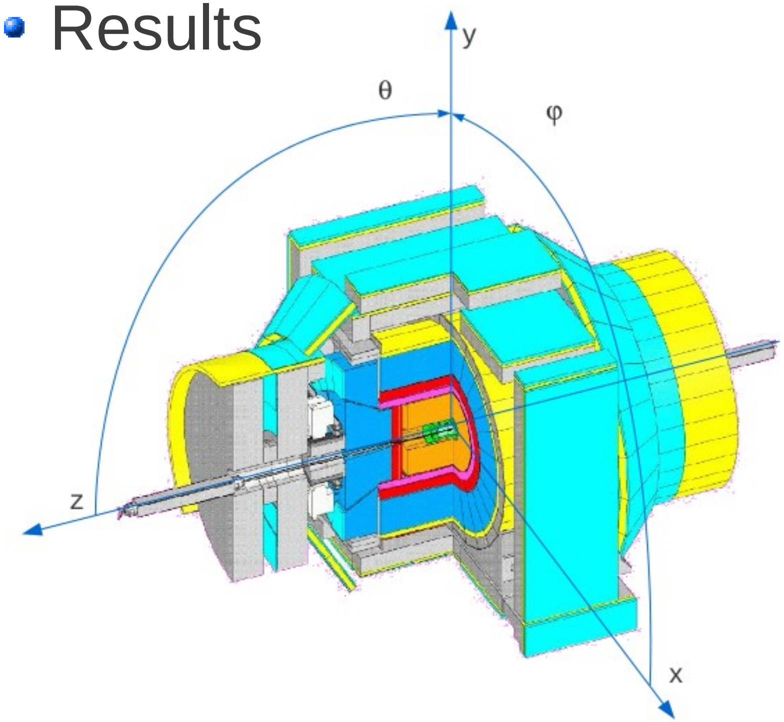


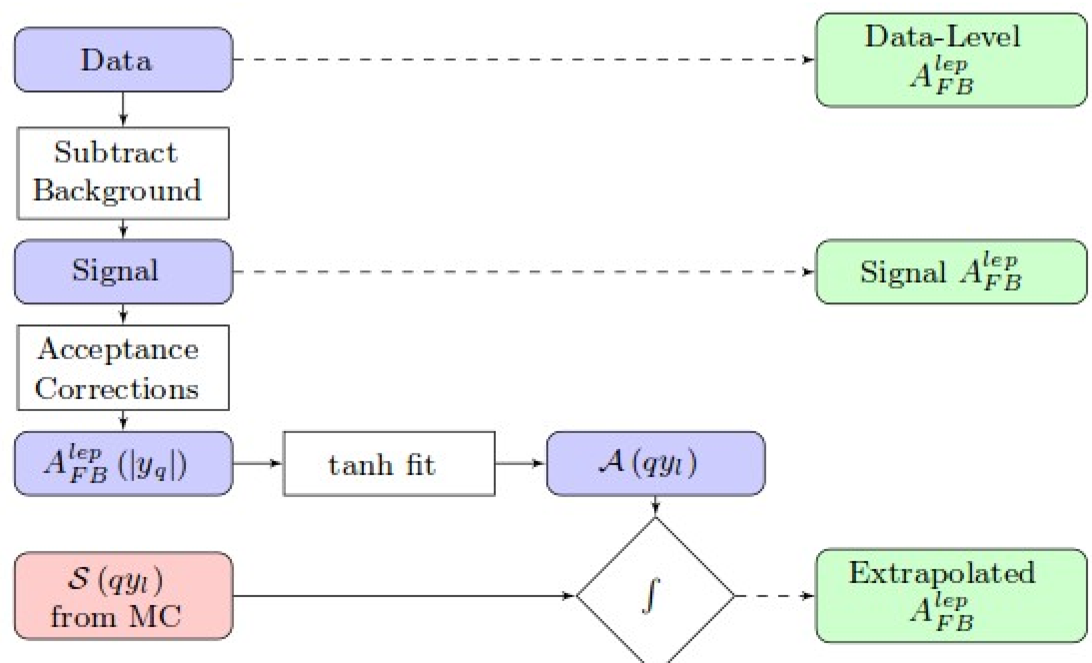
Measurement of leptonic asymmetry A^{lep}_{FB} with CDF

- Lepton + jets Event selection
- Background subtraction
- Acceptance corrections and extrapolation
- Systematic uncertainties
- Results

L = 9.4 fb^{-1}







Event selection

- Exactly 1 electron or muon with p_T > 20 GeV/c
- Missing E_T > 20 GeV
- 3 jets with E_T > 20 GeV
- At least 1 jet with E_T > 12 GeV
- At least 1 b-jet
- $H_T = \sum_{\mathrm{l,jets}} E_{\mathrm{T}} + E_{\mathrm{T}}^{\mathrm{miss}} > 220\ \mathrm{GeV}$

~70% Signal events

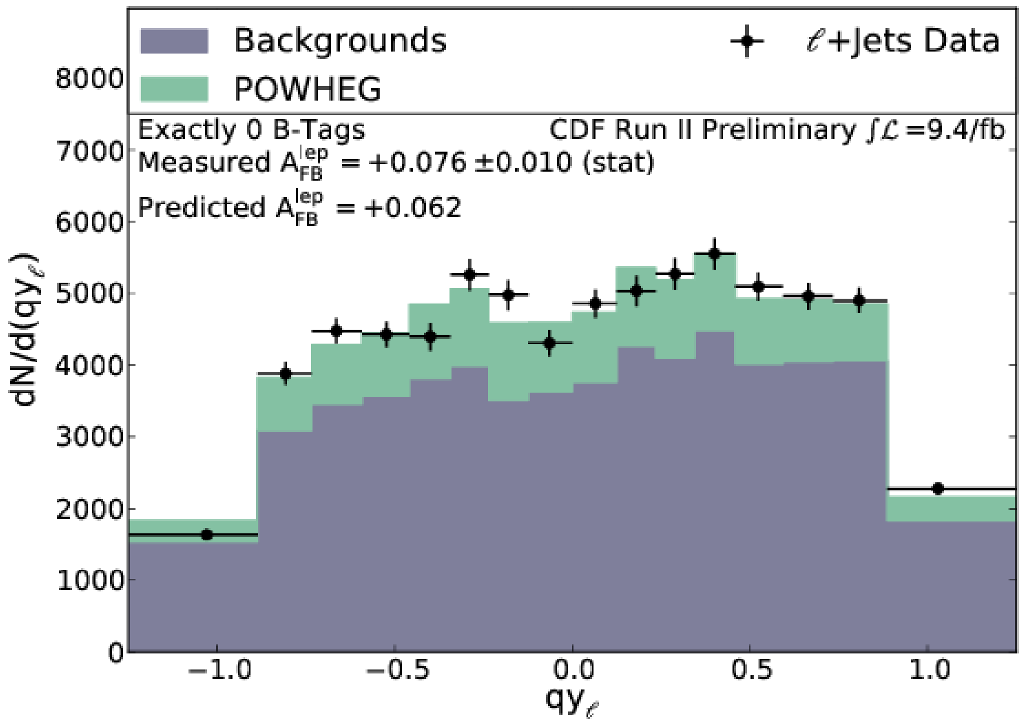
CDF Run II Preliminary $\int \mathcal{L} = 9.4/fb$

Process	Prediction		
Non-W	207	$\pm$	86
W+HF	481	$\pm$	178
W+LF	201	$\pm$	72
Single Top	67	$\pm$	6
Diboson	36	$\pm$	4
Z+jets	34	$\pm$	5
All Backgrounds	1026	$\pm$	210
$t\bar{t}$ 7.4pb	2750	$\pm$	426
Total Prediction	3776	$\pm$	476
Observed	3864		

Main background is W + jets

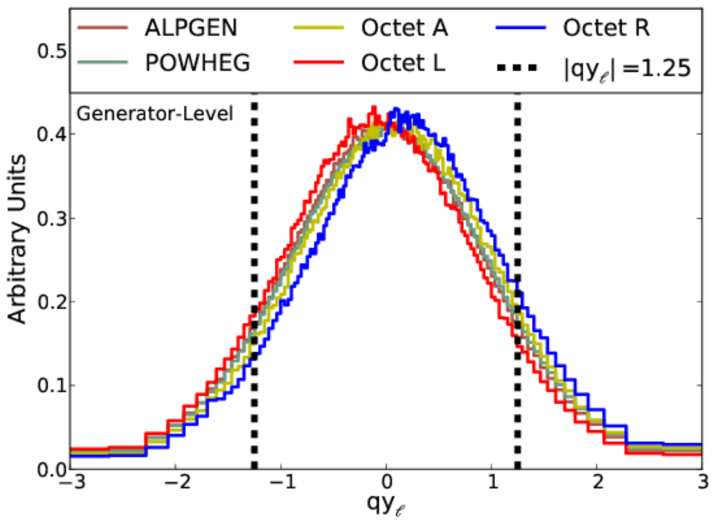
Background asymmetry

- W production is asymmetric
  - EW effects
  - Proton-antiproton collision (PDF)
- Check background modeling of A^{lep}_{FB} in background enhanced control region
- Antitag control region → veto b-tag jets
- W+jets background simulated with ALPGEN

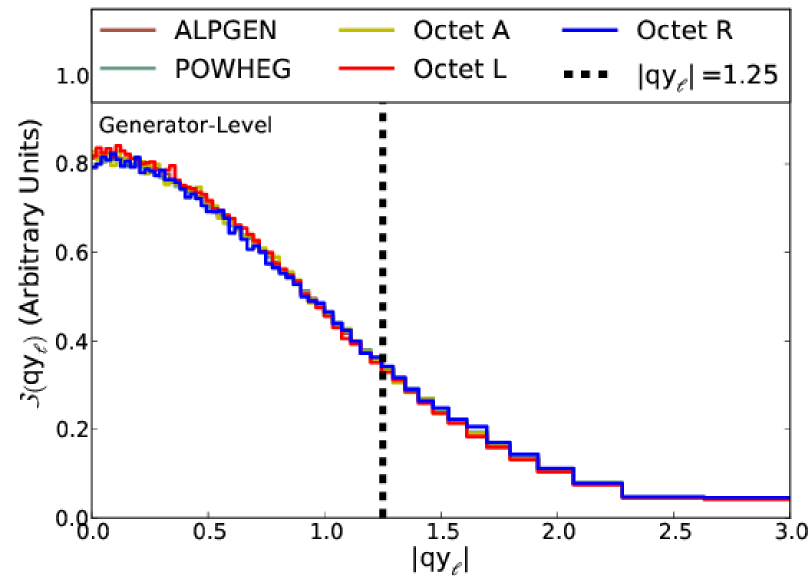


Good agreement of A^{lep}_{FB} in background enhanced control-region

Extrapolation method



$N(qy_l)$ is measured in a limited rapidity range
→ extrapolate to full range



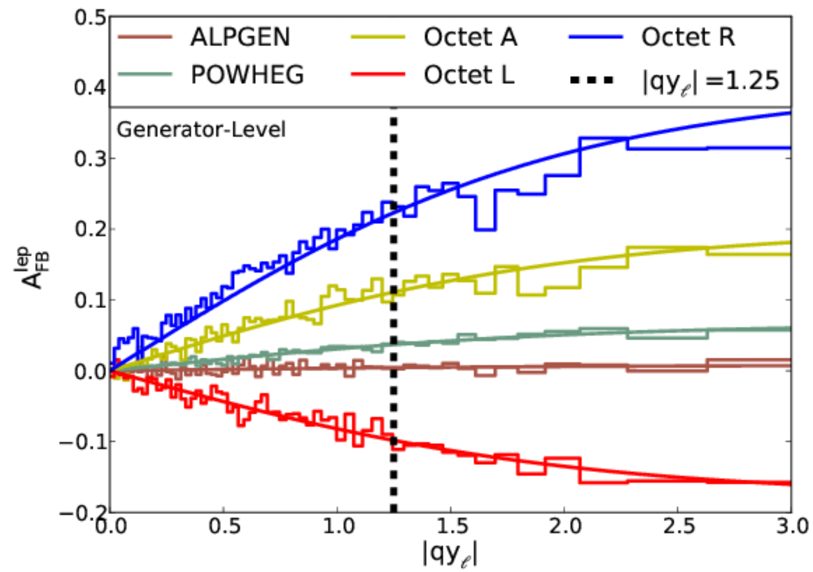
$N(qy_l)$ is decomposed into symmetric and asymmetric components

$$\mathcal{S}\left(qy_l\right) = \frac{N\left(qy_l\right) + N\left(-qy_l\right)}{2}$$

$$\mathcal{A}\left(qy_l\right) = \frac{N\left(qy_l\right) - N\left(-qy_l\right)}{N\left(qy_l\right) + N\left(-qy_l\right)}$$

$S(qy_l)$ is the same in all models

$A(qy_l)$ distinguish different models



Measured $A(qy_l)$ is

- Bin-by-bin unfolded to generator level
- Fitted with $$\mathcal{A}\left(qy_l\right) = a \tanh\left[\frac{1}{2} qy_l\right]$$
- Convoluted with $S(qy_l)$ to extract A^{lep}_{FB}

Extrapolation method - validation

Extrapolation method is validated on each of the reference models

- Apply acceptance correction and extrapolation procedure on simulated samples at detector-level
- Compare extrapolated A^{lep}_{FB} with generator-level A^{lep}_{FB}

Bin-by-bin acceptance corrections evaluated with POWHEG

CDF Run II Preliminary $\int \mathcal{L} = 9.4/fb$

Signal Model	True A_{FB}^{lep}	Extrapolated A_{FB}^{lep}
ALPGEN	$+0.003\,(1)$	-0.004
POWHEG	$+0.024\,(0)$	$+0.027$
Octet A	$+0.070\,(1)$	$+0.069$
Octet L	$-0.062\,(1)$	-0.062
Octet R	$+0.149\,(2)$	$+0.155$

The method is very stable across the different models

Systematic uncertainties

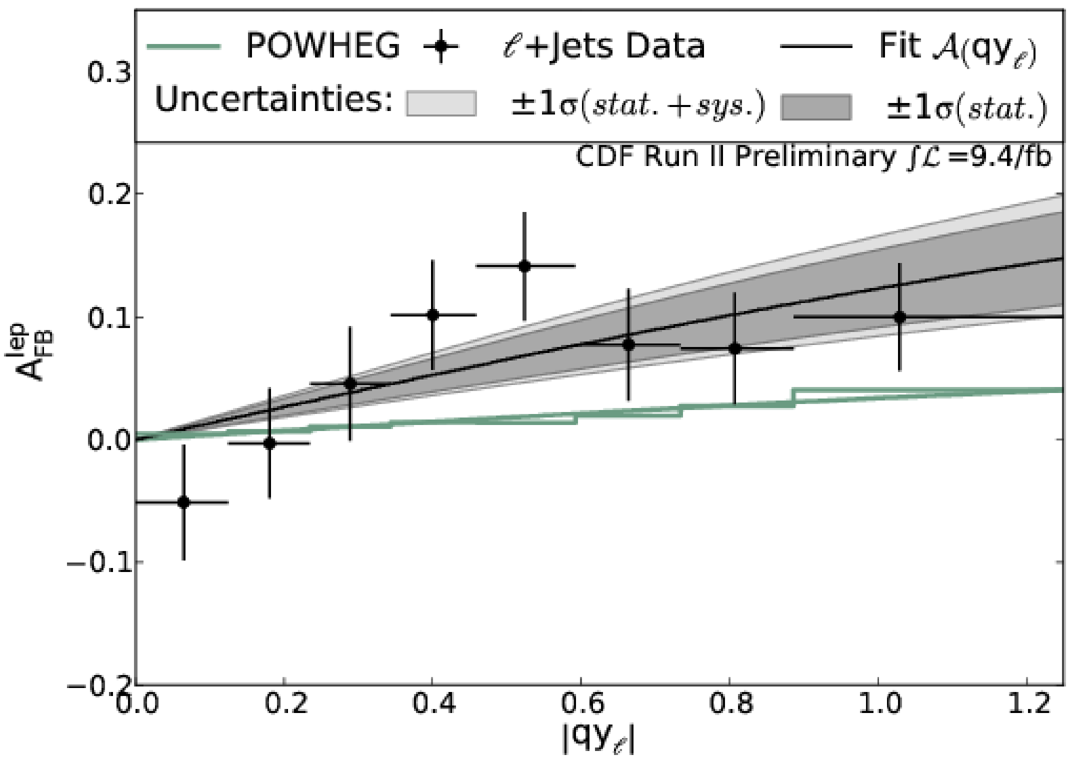
Main systematic uncertainties

- Background estimation
- Recoil Modeling – impact of p_T^{tt} modeling

CDF Run II Preliminary $\int \mathcal{L} = 9.4/fb$	
Source of Uncertainty	Value
Backgrounds	0.015
Recoil Modeling	$+0.013$ -0.000
Color Reconnection	0.0067
Parton Showering	0.0027
PDF	0.0025
JES	0.0022
IFSR	0.0018
Total Systematic	$+0.021$ -0.017
Data Statistics	0.024
Total Uncertainty	$+0.032$ -0.029

The measurement is statistically limited

Results



$$A^{lep}_{FB} = \frac{N(qy_l > 0) - N(qy_l < 0)}{N(qy_l > 0) + N(qy_l < 0)}$$

CDF data	$0.094 \pm 0.024\ ^{+0.022}_{-0.017}$
POWHEG	0.027
QCD + EW	0.038 ± 0.003
SM estimation based on CDF A_{FB}	0.076

Assume $A_{FB} / A^{lep}_{FB} = 2.17$ (POWHEG)

~ 2σ higher than prediction

CDF Run II Preliminary $\int \mathcal{L} = 9.4/fb$

Sample	N_{events}	Data	Signal	Fully Extrapolated
Electrons	1788	0.050 ± 0.024	0.050 ± 0.034	$0.062^{+0.052}_{-0.049}$
Muons	2076	0.081 ± 0.022	0.087 ± 0.029	$0.119^{+0.039}_{-0.037}$
Positive	1884	0.099 ± 0.023	0.110 ± 0.031	$0.125^{+0.042}_{-0.041}$
Negative	1980	0.036 ± 0.022	0.034 ± 0.031	$0.063^{+0.045}_{-0.042}$
Inclusive	3864	0.067 ± 0.016	0.070 ± 0.022	$0.094^{+0.033}_{-0.030}$

Consistent A^{lep}_{FB} measurements in e, μ, l^+, l^- subsamples

Summary and conclusions

- Leptonic asymmetry in $t\bar{t}$ production has been measured in the lepton + jets final state with the full Tevatron dataset
- Developed specific analysis techniques, extrapolation robust across SM and BSM models
- Measured $A^{lep}_{FB} = 0.094 \pm 0.024\,^{+0.022}_{-0.017}$
- ~2σ excess with respect to NLO prediction (including EW corrections)
- Compatible with a SM-like estimation from measured A_{FB}

→ Work in progress to measure A^{lep}_{FB} in the dilepton channel

Summary and conclusions

- Leptonic asymmetry in $t\bar{t}$ production has been measured in the lepton + jets final state with the full Tevatron dataset
- Developed specific analysis techniques, extrapolation robust across SM and BSM models
- Measured $A^{lep}_{FB} = 0.094 \pm 0.024\ ^{+0.022}_{-0.017}$
- ~2σ excess with respect to NLO prediction (including EW corrections)
- Compatible with a SM-like estimation from measured A_{FB}

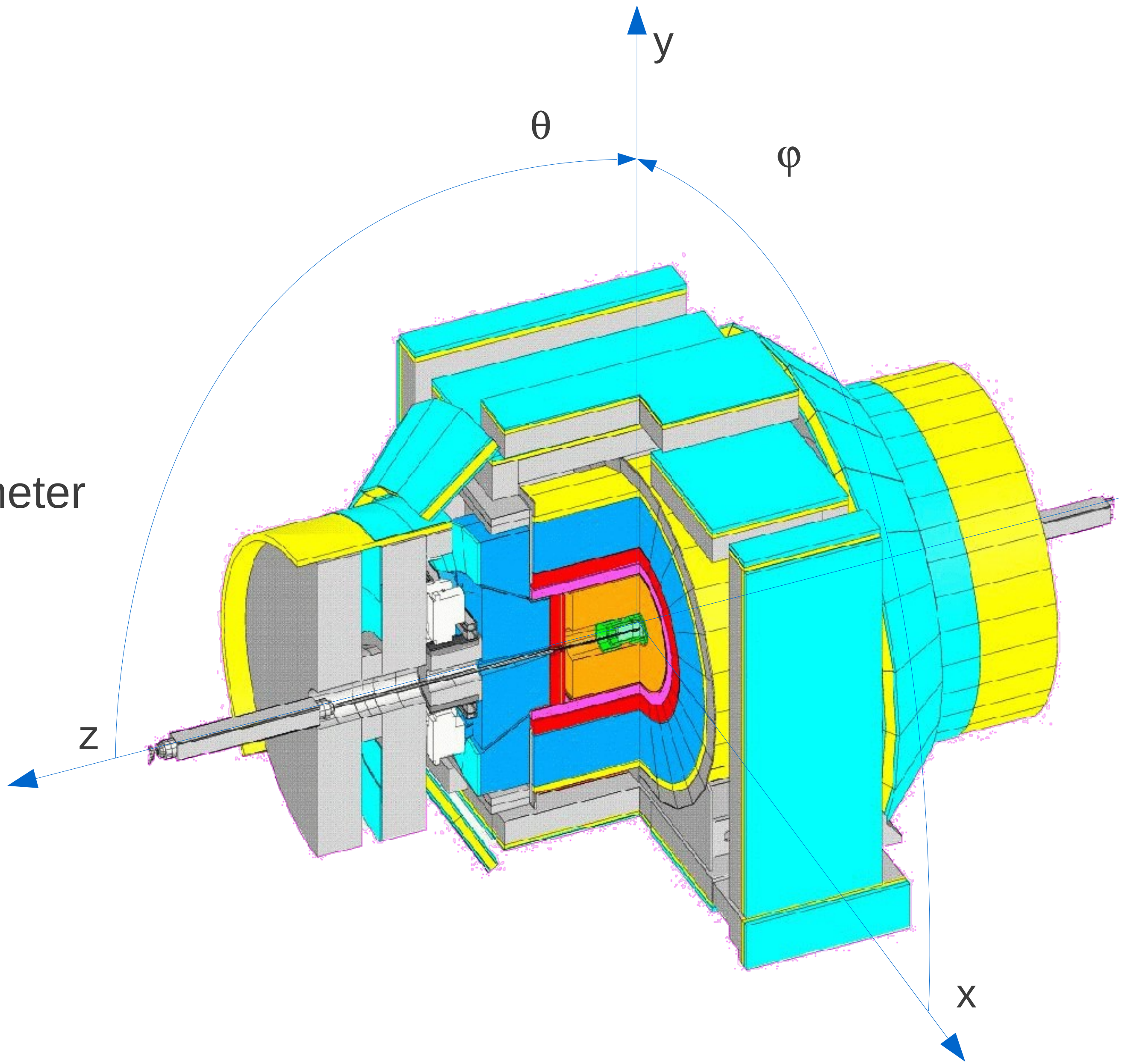
→ Work in progress to measure A^{lep}_{FB} in the dilepton channel

Thanks for your attention!

BACKUP

CDF Detector

- Tracking system
  - Silicon detectors
  - Drift chambers COT
- 1.4 T Magnetic field
- Calorimeter
  - Electromagnetic calorimeter
  - Hadronic calorimeter
- Muon detectors
  - Wire chambers
  - Scintillators
- 3 Level Trigger System
  - Level 3 → ~ 100 Hz



Decomposition formulas

$$\mathcal{S}(qy_l) = \frac{N(qy_l) + N(-qy_l)}{2}$$

$$\mathcal{A}(qy_l) = \frac{N(qy_l) - N(-qy_l)}{N(qy_l) + N(-qy_l)}$$

$$N(qy_l) = \mathcal{S}(qy_l) \times \begin{cases} 1 + \mathcal{A}(qy_l) & qy_l > 0 \\ 1 - \mathcal{A}(qy_l) & qy_l < 0 \end{cases}$$

$$N(qy_l > 0) = \int_0^\infty dqy_l \left[\mathcal{S}(qy_l) \times (1 + \mathcal{A}(qy_l))\right]$$

$$N(qy_l < 0) = \int_0^\infty dqy_l \left[\mathcal{S}(qy_l) \times (1 - \mathcal{A}(qy_l))\right]$$

$$A_{FB}^{lep} = \frac{N(qy_l > 0) - N(qy_l < 0)}{N(qy_l > 0) + N(qy_l < 0)} = \frac{\int_0^\infty dqy_l \left[\mathcal{A}(qy_l) \times \mathcal{S}(qy_l)\right]}{\int_0^\infty dqy_l \mathcal{S}(qy_l)}$$